The removal of perennial energy crops: techniques and impacts

September 2015

Perennial crops such as ***miscanthus*** or ***giant reed*** are today considered as promising energy crops because of their high level of biomass production, low nutrient requirements and low greenhouse gas emissions. In fact, after an establishment phase of 3 to 5 years, biomass yields remain nearly stable for 15 to 20 years. Crop yields tend to decrease after this period of time, leading necessarily to the removal of those crops in order to re-establish either new rhizomes or to come back to more traditional annual crops. However, if planting operations are well addressed by scientific and technical publications, literature focusing on the removal phase and its potential impacts on the following crops and the environment remain limited. The LogistEC project has tried to fill this gap by testing in England and Italy, (1) best technics to remove both miscanthus and giant reed and (2) evaluate eventual impacts on succeeding crops.

DETERMINING BEST PRACTICES FOR REVERTING PERENNIAL ENERGY CROPS

Different practices have been tested all along the duration of the LogistEC project for reverting perennial crops:

- On the Woburn experimental farm in the SE of England (UK), it was decided to return two crops of miscanthus to annual arable cropping, one on a sandy loam soil and the other one on a clay loam soil. The crops had been planted in 2001. Alongside were areas of set-aside (dominated by C3 grasses) and continuous arable cropping.
  During summer 2011, the miscanthus and set-aside areas were sprayed with glyphosate, mown and sprayed again with glyphosate. Both applications of glyphosate were of products containing 360 g l^{-1} of active ingredient at 4 l ha^{-1} in 200 l water through conventional nozzles. In September, the miscanthus and set-aside areas were sub-soiled (cultivated at 0.35 – 0.4 m depth) and all areas ploughed. On the sandy loam site it was considered necessary to rotorvate the areas formerly cropped with miscanthus to further break up the mass of rhizome on the soil surface in order to create a seedbed for winter wheat. The clay loam site was drilled with beans later in October using a cultivator drill which could operate amongst the rhizome mass.
  The sites were then cropped as described in Table 1 and all arable crops were treated as standard farm practice.

- In central Italy at the Agro-environmental Research Centre Enrico Avanzi (Pisa), 10 year-old crops of miscanthus and giant reed growing in a loamy soil were removed in 2013. The effect of two technical strategies was studied:
  1) three herbicide applications (glyphosate-based herbicide at 3°600 g ha^{-1}in total), after Spring sprouting, when the plants reached 20-30 cm in height (May), at the beginning of Summer and at the end of Summer;

The LogistEC project is financially supported by the 7th Framework Programme for Research and Technological Development (GA n.311858). The sole responsibility for the content of this publication lies with the authors. It does not represent the opinion of the European Commission which is not responsible for any use that may be made of the information contained therein.

2) ploughing at depth of 0.30 m and disk harrowing carried out before Spring sprouting, followed by two herbicide applications (glyphosate-based herbicide at 3°600 g ha^{-1} in total) at the beginning and at the end of Summer. The plots were then left fallow during the two following years.

KEY OUTCOMES

In the UK, occasional miscanthus shoot could be seen in the arable crops after the crop removal, but never in sufficient quantities to require specific action.

In Italy, the efficiency of the two strategies has been evaluated by counting the number of new emerging stems at different fixed periods:

- ✓ For both crops, the second strategy (mechanical and chemical) was the most effective.
- ✓ The removal of miscanthus seems to be more difficult than for giant reed, probably because miscanthus rhizomes are thinner compared to those of giant reed and can easily break in multiple fragments all with viable buds.

Overall, the combination of mechanical and chemical weeding seems to represent the best technical solution to remove perennial crops such as miscanthus or giant reed. However, one year of production was lost in all cases. The main limit of this strategy is the large use of a non-selective herbicide such as glyphosate and its associated environmental impacts (water pollution, reduction of biodiversity etc.). However, in the cultivation of perennial crops, considering a crop cycle of 15-20 years, the use of herbicide could be limited to the establishment year and the destruction phase, *i.e.* a much lower frequency than in conventional annual crops. A fully-mechanical strategy was not directly tested in the project but could be possible. However, it would probably result in a longer destruction phase with a greater number of mechanical interventions.

The LogistEC project is financially supported by the 7th Framework Programme for Research and Technological Development (GA n.311858). The sole responsibility for the content of this publication lies with the authors. It does not represent the opinion of the European Commission which is not responsible for any use that may be made of the information contained therein.

LogistEC
Logistics for Energy Crops Biomass

Figure 1. Some rhizome root associations remained poorly broken up early in 2013 on the sandy soil in the UK, despite rotorvating 18 months earlier. They were not considered an impediment to arable cropping.

IMPACT OF PERENNIAL ENERGY CROP REMOVAL ON SOIL AND SUBSEQUENT CROPS

Following the removal of energy crops on the Woburn experimental farm (UK), yields of the following crops have been registered and are presented in the bellow table. Most noteworthy results have been the low wheat yield on the sandy loam in 2012 (a second wheat crop) following continuous arable cropping due to infection by take all (*Gaeumannomyces graminis tritici*) and the low bean yield in 2013 which may be due to the short interval since the previous bean crop in 2010. Take all infections on the sandy loam soils on the farm can often be severe.

On the clay loam soil the wheat crops in the continuous arable cropping sequence suffered severe competition from blackgrass (*Alopecurus myosuroides*) which was present in the field in large numbers and showed resistance to the major herbicides used in wheat cropping. The major effect of set-aside or miscanthus was positive in acting as a break crop in an arable rotation.

The LogistEC project is financially supported by the 7th Framework Programme for Research and Technological Development (GA n.311858). The sole responsibility for the content of this publication lies with the authors. It does not represent the opinion of the European Commission which is not responsible for any use that may be made of the information contained therein.

Years	Sandy loam soil				Clay loam soil			
		Preceding crops				**Preceding crops**		
2010		W B	Set-aside	Miscanthus		W W	Set-aside	Miscanthus
2011		W W	Set-aside	Miscanthus		W W	Set-aside	Miscanthus
		Annual crop yields				**Annual crop yields**		
2012	W W	4.1	8.2	7.4	W B	2.1	1.8	2.3
2013	W B	2.1	3.9	3.2	W W	3.4	8.6	7.9
2014	W W	11.9	11.0	11.4	W W	3.0	7.8	8.2
2015	O R	6.0	6.2	6.4	O R	4.3	4.3	4.2

Table 1. Rotations and crop yields (t ha-1, 15% moisture for wheat and beans, 9% moisture for oilseed rape) following 10 years of set-aside or miscanthus. Data from two soil types at the Woburn Experimental Farm, UK. W W = winter wheat, W B = winter bean, O R = oilseed rape.

In order to investigate the effect of incorporating the set-aside and miscanthus residue into the soil on nitrogen availability, the crops from 2012 onwards were also grown without artificial nitrogen inputs. Soil mineral nitrogen was measured each Spring. Soil nitrogen status was unlikely to affect the growth of the winter bean crop and take all and blackgrass influenced the wheat crops in a similar way to that in Table 1 so that no indication of mineralization capacity was collected. Soil mineral nitrogen data showed no differences at the time of sampling each year.

On the sandy loam soil, there was an increase in soil carbon (%C in soil) where the perennial cropping had been in place for 10 years, and the increase persisted until 2014 (the latest data available, Table 2.). However, the increase in carbon was all in the surface horizon (0 – 23 cm), or plough layer, where the carbon may be considered most vulnerable to subsequent loss. The sampling method tended not to capture the large rhizome fragments left in the surface horizon following miscanthus, and so the value in Table 2 may be an underestimate of %C under a former miscanthus crop. Protecting and preserving that large carbon store could be a crucial challenge when reverting from energy crop to arable cropping.

Depth	Arable	Set-aside	Miscanthus
0 – 23 cm	10.0	12.1	13.6
24 – 60 cm	5.7	5.5	5.8
61 – 90 cm	2.6	2.1	2.3

Table 2. Soil carbon concentration (g kg-1) in the sandy loam soil in 2014 following continuous arable cropping or 10 years of set-aside or miscanthus. The L.S.D. was 1.3.

In Italy, higher CO_2 emissions from soil were observed during the destruction phase compared to mature crops and this increase was higher when the soil tillage was performed.

The LogistEC project is financially supported by the 7th Framework Programme for Research and Technological Development (GA n.311858). The sole responsibility for the content of this publication lies with the authors. It does not represent the opinion of the European Commission which is not responsible for any use that may be made of the information contained therein.

Figure 2. Giant reed in Italy in May 2015. Left part: control plot. Right part: 2 years after mechanical and chemical destruction (fallow plot).

KEY OUTCOMES

- ✓ Reverting miscanthus or giant reed is possible with conventional farm practice; however one year of production is lost.
- ✓ Perennial crops can act as break crops in an arable rotation.
- ✓ In the UK, there were no apparent effects on the nitrogen dynamics of the soil system. A higher soil carbon concentration than in annual crops was still visible in the surface layer three years after the crop removal.
- ✓ The soil carbon accumulated during 10 years of perennial land use was concentrated in the surface horizon and was vulnerable to subsequent loss.

The LogistEC project is financially supported by the 7th Framework Programme for Research and Technological Development (GA n.311858). The sole responsibility for the content of this publication lies with the authors. It does not represent the opinion of the European Commission which is not responsible for any use that may be made of the information contained therein.